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# Predictors of Readmission, for Patients with Chronic Obstructive Pulmonary Disease (COPD) – A Systematic Review

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**Introduction:** Chronic obstructive pulmonary disease (COPD) is the third-leading cause of death globally and is responsible for over 3 million deaths annually. One of the factors contributing to the significant healthcare burden for these patients is readmission. The aim of this review is to describe significant predictors and prediction scores for all-cause and COPD-related readmission among patients with COPD.

**Methods:** A search was conducted in Ovid MEDLINE, Ovid Embase, Cochrane Database of Systematic Reviews, and Cochrane Central Register of Controlled Trials, from database inception to June 7, 2022. Studies were included if they reported on patients at least 40 years old with COPD, readmission data within 1 year, and predictors of readmission. Study quality was assessed. Significant predictors of readmission and the degree of significance, as noted by the *p*-value, were extracted for each study. This review was registered on PROSPERO (CRD42022337035).

**Results:** In total, 242 articles reporting on 16,471,096 patients were included. There was a low risk of bias across the literature. Of these, 153 studies were observational, reporting on predictors; 57 studies were observational studies reporting on interventions; and 32 were randomized controlled trials of interventions. Sixty-four significant predictors for all-cause readmission and 23 for COPD-related readmission were reported across the literature. Significant predictors included 1) pre-admission patient characteristics, such as male sex, prior hospitalization, poor performance status, number and type of comorbidities, and use of long-term oxygen; 2) hospitalization details, such as length of stay, use of corticosteroids, and use of ventilatory support; 3) results of investigations, including anemia, lower $FEV_1$, and higher eosinophil count; and 4) discharge characteristics, including use of home oxygen and discharge to long-term care or a skilled nursing facility.

**Conclusion:** The findings from this review may enable better predictive modeling and can be used by clinicians to better inform their clinical gestalt of readmission risk.

**Keywords:** predictors, readmission, chronic obstructive pulmonary disease

## Introduction

Chronic obstructive pulmonary disease (COPD) is a common respiratory condition characterized by persistent airflow limitation[1] and is thought to affect over 10% of the population.[2] As a consequence of its chronicity, COPD is responsible for over 3 million deaths globally, making it the third most common cause of death.[3]

Patients with COPD commonly require hospitalized care, and COPD is one of the most common causes of hospitalization, among chronic diseases.[4] Moreover, a notable proportion of patients with COPD will be readmitted, making readmission one of the factors contributing to the significant healthcare burden for these patients. It has been estimated that up to 50% of patients diagnosed with COPD are readmitted within 30 days of initial discharge in the USA.[5] In addition to the utilization of healthcare resources, readmission is associated with a worse overall prognosis.[6] Over the past decade, there has been an increased interest in identifying predictors and predictive models for readmission.[7] Several systematic reviews have attempted



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to summarize the literature, but they only focused on all-cause or COPD-related readmission alone, and/or did not undertake a quality assessment of the included studies.[8–10] In addition, given the rapidly developing literature, with many studies being reported in the past few years, these systematic reviews may not account for current findings.

The aim of this systematic review is to describe significant predictors and prediction scores for all-cause and COPD-related readmission among patients with COPD.

# Methods

This review was registered a priori on PROSPERO (CRD42022337035) and reported as per the PRISMA statement.

## Search Strategy

A comprehensive search strategy was developed for Ovid MEDLINE, Ovid Embase, Cochrane Database of Systematic Reviews, and Cochrane Central Register of Controlled Trials from database inception to June 7, 2022, using a combination of database-specific subject headings and text words for the main concepts of COPD and hospital readmissions. An expanded search filter for clinical prediction guides was used. Results were limited to adult human studies. No other limits were applied (Appendix 1).

## Eligibility Criteria

Two review authors (RC, OWS) independently screened articles for their eligibility for inclusion. A calibration exercise of 20 articles was undertaken to ensure concordance between reviewers. Discrepancies were resolved by discussion and consensus. If consensus could not be achieved, a third review author (RW) participated in the discussion to resolve discrepancies.

Articles were eligible after level 1 title and abstract screening, if they reported on primary research articles reporting on patients with COPD and readmission. Secondary research articles, such as review articles and economic analyses, as well as editorials/commentaries, were excluded at this stage. Studies included after level 2 full-text screening eligibility criteria required studies to report on patients at least 40 years old with COPD, readmission data within 1 year of a COPD hospitalization, and predictors of readmission. Studies including patients admitted for reasons unrelated to acute exacerbations of COPD (eg pneumonia, acute hypercapnic respiratory failure, obstructive sleep apnea, lung cancer, anxiety/depression) and studies reporting on home care/telemonitoring were excluded at this stage, to limit included articles to only patients with COPD.

## Data Extraction

Two of the three review authors (RC, OWS, JHBI) conducted data extraction. As with screening, discrepancies were resolved by discussion and consensus, with or without the input of a third reviewer (RW). Study characteristics of country, sample size, age of participants, and percentage of females enrolled in study were noted. Studies were classified as either assessing predictors or assessing interventions. Studies assessing interventions were further subclassified as either observational cohort studies or randomized controlled trials. Significant predictors of readmission and the degree of significance, as noted by the *p*-value, were extracted for each study. For studies that did not report *p*-values, *p*-values were calculated based on the provided statistics (eg odds ratio and 95% confidence intervals) where possible.

## Study Quality

Study quality was assessed for each study. For randomized controlled trials, the risk of bias version 2 tool was used.[11] For observational studies reporting on interventions, the ROBINS-I tool was used.[12] For observational studies reporting on predictors, the ROBINS-E tool was used.[13]

## Synthesis

Significant predictors were reported by the time of readmission post-discharge and the degree of significance. Predictors were reported as significant predictors for the timepoint of 1-month readmission, the interval of 2–3-month readmission, and the interval of 6–12-month readmission. Predictors were further reported based on whether they were significant at a type I error of 0.05, type I error of 0.01, or no degree of significance available. Significant predictors, as reported by the authors (Supplementary Tables 1 and 2), were grouped together into similarly reported predictors across the literature (eg all mentions of hospital length of stay were grouped together).

Because of the non-uniform reporting of non-significant predictors, where some studies explicitly reported non-significant predictors in the methods/results and others only mentioned significant predictors, non-significant predictors were not presented.

## Results

In total, 4035 articles were identified from the database search. After 970 duplicates were removed, 3065 records were screened. Ultimately, 242 articles[14–255] reporting on 16,471,096 patients were included in this review (Figure 1). Across the literature, there was generally a low risk of bias (Figure 2).

Overall, 153 studies were observational studies reporting on predictors; 57 studies were observational studies reporting on interventions; and 32 were randomized controlled trials of interventions. The studies were published between 1997 and 2022, with over half of the studies published since 2017. Over one-third of articles (91 studies, 37.6%) originated from the USA; 31 (12.8%) studies originated from Spain, 14 (5.8%) from Canada, 13 (5.4%) from the UK, and 13 (5.4%) from China. Sample sizes ranged from 8 to 4,587,542. The mean/median age was greater than 60

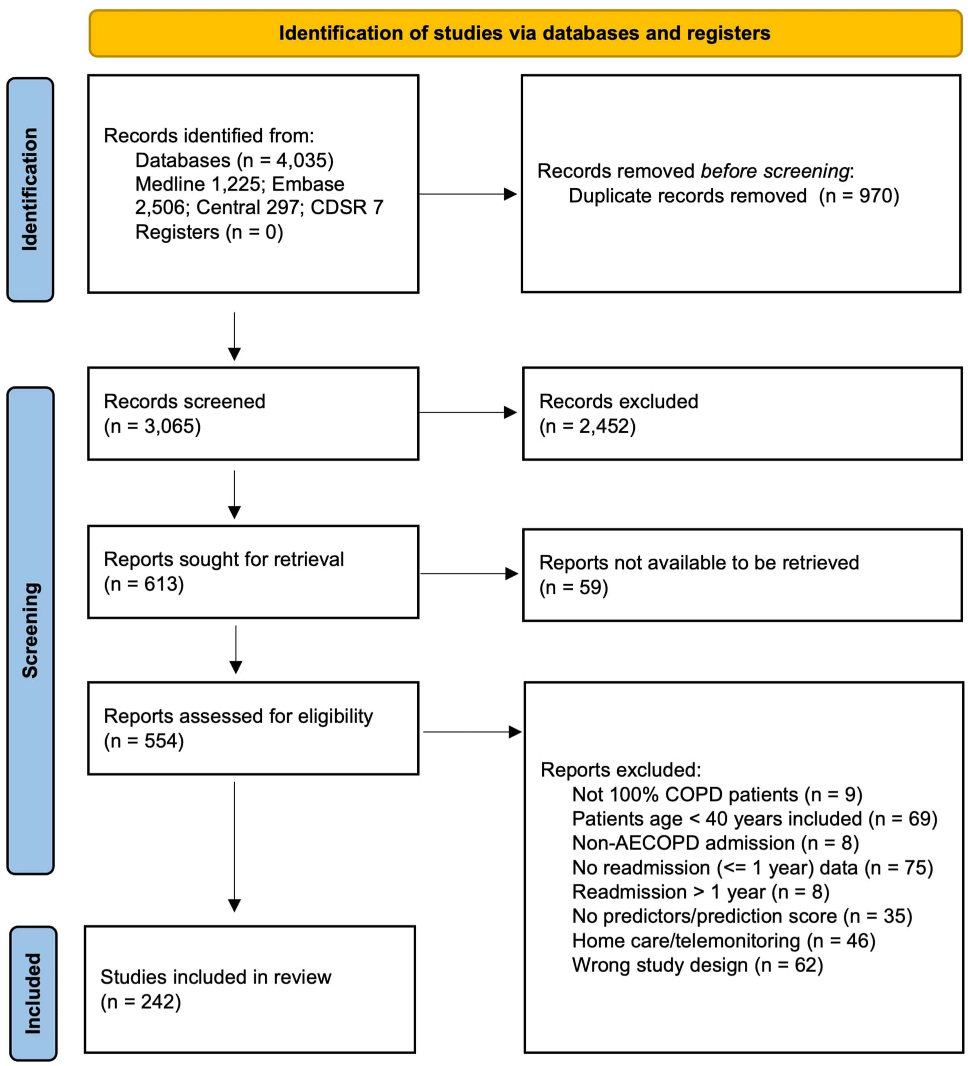


**Figure 1** PRISMA flow diagram.

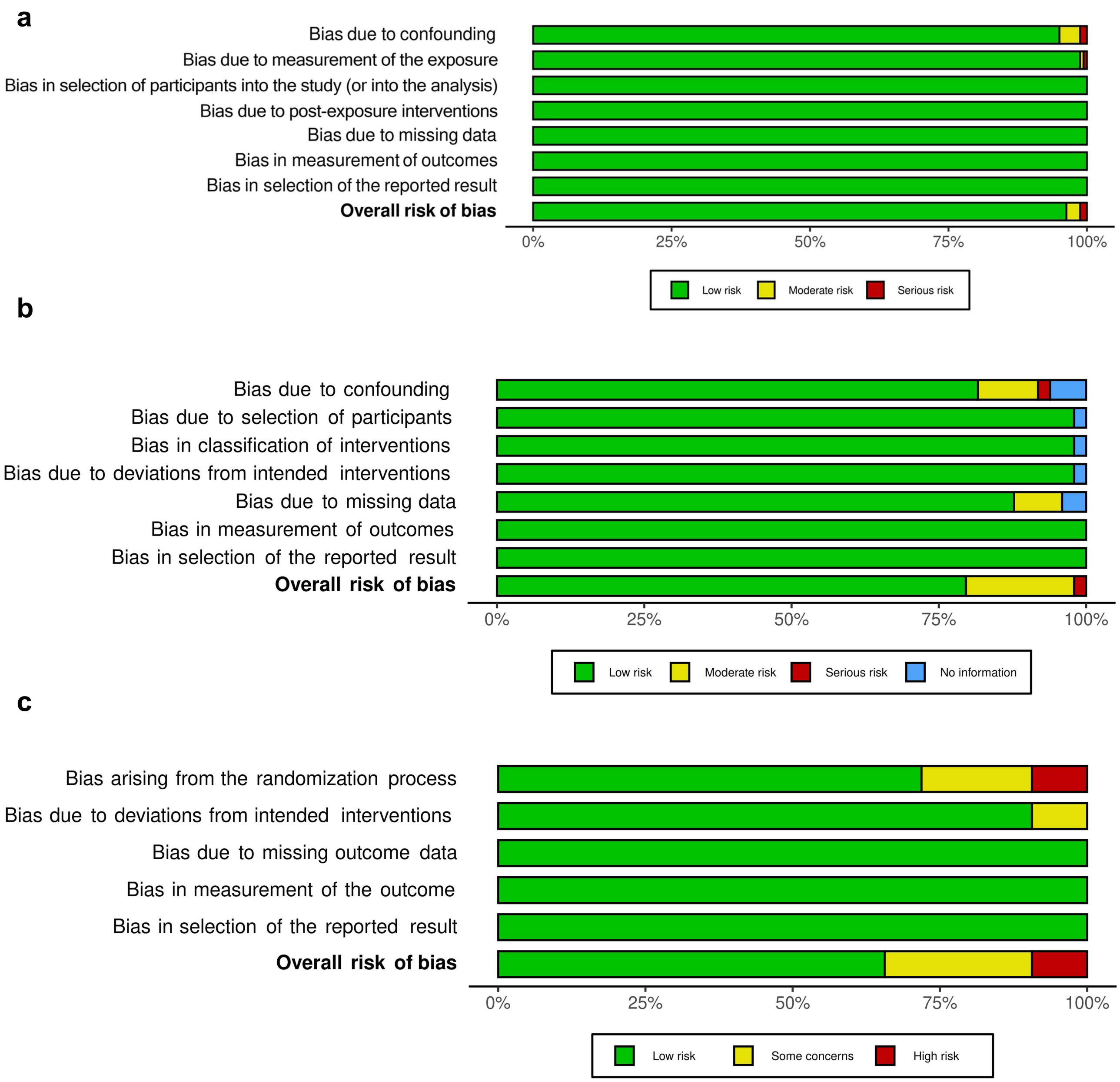


**Figure 2** Quality assessment: (**a**) studies assessing predictors (ROBINS-E); (**b**) cohort studies assessing interventions (ROBINS-I); (**c**) randomized controlled trials assessing interventions (RoB 2).

years for nearly all studies. The percentage of females in a study ranged from 0.0% to 80.0%. Individual study characteristics are reported in Table 1 and Table 2.

A total of 64 significant predictors for all-cause readmission were reported across the literature. Summarizing across all readmission time frames, male sex, prior hospitalization, poorer performance status/activities of daily living, and older age were the most frequently reported patient characteristics that were predictors of readmission. Other significant predictors were COPD severity, alcohol/drug abuse, malnutrition, and history of community-acquired pneumonia (Figure 3a). Heart failure, mental health comorbidity, higher Charlson comorbidity index, diabetes, higher number of comorbidities, chronic kidney disease, and cancer were among the most commonly reported comorbidity predictors of readmission (Figure 3b). Among medications used prior to admission that were significant of readmission, long-term oxygen therapy was the most commonly reported predictor (Figure 3c). Hospital length of stay, non-invasive ventilation, intubation, and admission to the intensive care unit were the most common hospital care predictors of readmission

**Table 1** Studies Assessing Predictors

| Study | Country | n | Age (years) | | % Female |
|---|---|---|---|---|---|
| | | | Mean ± SD | Median (IQR) | |
| Abrams 2011[14] | USA | 28,156 | 69.1±10.6 | | 3.1% |
| Abusaada 2017[15] | USA | 1419 | 65.1±2.3 | | 47.7% |
| Agarwal 2016[18] | USA | 7257 | | 75–84 | 64.2% |
| Aksoy 2018[19] | Turkey | 2727 | 69.8±10.2 | | 31.5% |
| Al Aqqad 2017[20] | Malaysia | 81 | | 72.0 (66.4–78.0) | 2.5% |
| Almagro 2006[21] | Spain | 129 | 72.0±9.2 | | 7.0% |
| Almagro 2012[22] | Spain | 606 | 72.6±9.9 | | 2.0% |
| Almagro 2014[23] | Spain | 983 | 72.3±9.7 | | 8.5% |
| Alpaydin 2021[24] | Turkey | 300 | 73.1±10.1 | | 28.3% |
| Alqahtani 2021[25] | UK | 82 | 71.0±10.4 | | 51.2% |
| Bade 2019[29] | USA | 48,888 | 68.7±10.1 | | 3.7% |
| Bahadori 2009[30] | Canada | 310 | 74.0±12.0 | | 46.5% |
| Baker 2013[31] | USA | 6095 | | 55–59 | 58.9% |
| Barba 2012[33] | Spain | 275,512 | 72.0±15.4 | | 30.0% |
| Bartels 2018[34] | Canada | 511 | 66.5±13.3 | | 35.2% |
| Belanger 2018[36] | Canada | 479 | 68.9±9.4 | | 48.0% |
| Bernabeu-Mora 2017[38] | Spain | 103 | 71.0±9.1 | | 6.8% |
| Bishwakarma 2017[40] | USA | 6066 | 76.9±7.2 | | 67.3% |
| Boeck 2014[41] | Switzerland | 43 | Not reported | | 53.5% |
| Boixeda 2017[42] | Spain | 120 | 72.9±8.6 | | 2.5% |
| Bollu 2013[43] | USA | 2463 | 68.6±10.6 | | 57.2% |
| Bollu 2017[44] | USA | 13,675 | 67.1±12.4 | | 55.6% |
| Breyer-Kohansal 2019[45] | Austria | 823 | 68.5±10.2 | | 40.9% |
| Brownridge 2017[46] | Australia | 130 | 72.9±10.7 | | 51.6% |
| Buhr 2019[49] | USA | 1,622,983 | 68.0±11.9 | | 58.9% |
| Buhr 2020[48] | USA | 1,622,983 | 68.0±11.9 | | 57.8% |
| Candrilli 2015[50] | USA | 264,526 | 67.6±11.2 | | 50.9% |
| Carneiro 2010[51] | Portugal | 45 | 68±12.4 | | 15.6% |
| Chan 2011[52] | Hong Kong | 65,497 | 76.8±9.6 | | 23.0% |
| Chang 2014[53] | China | 135 | | 66 (60–74) | 11.9% |
| Chawla 2014[54] | USA | 54 | 70.0±12.0 | | 70.0% |
| Chen 2006[57] | Taiwan | 145 | 72.2±10.0 | | 26.9% |

(*Continued*)

**Table 1** (Continued).

| Study | Country | n | Age (years) | | % Female |
|---|---|---|---|---|---|
| | | | Mean ± SD | Median (IQR) | |
| Chen 2009[56] | Canada | 108,726 | 72.3±10.9 | | 45.5% |
| Chen 2021[55] | China | 636 | 70.8±9.9 | | 33.2% |
| Chu 2004[58] | Hong Kong | 110 | 73.7±7.6 | | 22.7% |
| Chung 2010[59] | Australia | 100 | 70.6±9.5 | | 44.0% |
| Coban Agca 2017[60] | Turkey | 1490 | 67.7±11.1 | | 35.0% |
| Connolly 2006[62] | New Zealand | 7113 | | 65–74 | 47.7% |
| Couillard 2017[65] | Canada | 167 | 71.4±10.3 | | 48.5% |
| Coventry 2011[66] | UK | 79 | 65.3±9.9 | | 44.3% |
| Crisafulli 2014[68] | Spain | 123 | 69.4±9.8 | | 6.6% |
| Crisafulli 2015[70] | Spain | 125 | 69.2±9.8 | | 6.4% |
| Crisafulli 2016[69] | Spain | 110 | 70.5±9.6 | | 6.4% |
| de Miguel-Diez 2016[74] | Spain | 301,794 | 74.8±10.0 | | 14.0% |
| Duman 2015[76] | Turkey | 1704 | Not reported | | 34.5% |
| Ehsani 2019[79] | USA | 42 | 70.4±8.1 | | 33.3% |
| Emtner 2007[80] | Sweden | 21 | 65.0±9.3 | | 66.7% |
| Eriksen 2010[81] | Denmark | 300 | 72.1 | | 61.7% |
| Ernst 2019[82] | Canada | 203,642 | Not reported | | Not reported |
| Euceda 2018[83] | USA | 272 | 73.2±12.4 | | 56.3% |
| Fernandez-Garcia 2020[84] | Spain | 253 | 68.99.8 | | 22.5% |
| Fu 2015[85] | USA | 15,755 | 71.0±12.5 | | 52.9% |
| Ganapathy 2017[86] | USA | 11,496 | 70.7±10.8 | | 52.5% |
| Garcia-Aymerich 2003[87] | Spain | 340 | 69±9 | | Not reported |
| Garcia-Pachon 2021[89] | Spain | 106 | 73±10 | | 21.7% |
| Garcia-Sanz 2020[90] | Spain | 602 | 73.8±10.6 | | 14.0% |
| Gavish 2015[91] | Israel | 195 | 66±10 | | 17.4% |
| Ghanei 2007[97] | Iran | 98 | 58.3±11.0 | | 37.0% |
| Giron 2009[98] | Spain | 78 | 71±10 | | 0.0% |
| Glaser 2015[99] | USA | 617 | Not reported | | Not reported |
| Gonzalez 2008[100] | Spain | 112 | 69.3±7.5 | | Not reported |
| Goto 2017[102] | USA | 845,465 | 70 | | 59.0% |
| Goto 2018[101] | USA | 76,697 | | 76 (71–83) | 59.6% |
| Goto 2020[103] | USA | 905 | | 76 (68–82) | 54.0% |

(*Continued*)

**Table 1** (Continued).

| Study | Country | n | Age (years) | | % Female |
|---|---|---|---|---|---|
| | | | Mean ± SD | Median (IQR) | |
| Gudmundsson 2005[104] | Sweden | 406 | 69.2±10.5 | [redacted] | 51.2% |
| Guerrero 2016[105] | Spain | 378 | 71.4±10.0 | [redacted] | 15.9% |
| Hajizadeh 2015[108] | USA | 4791 | 74.3±6.4 | [redacted] | Not reported |
| Hakansson 2020[109] | Denmark | 4022 | [redacted] | 73.1 (63.7–81.1) | 55.2% |
| Harries 2017[110] | UK | 19,551 | 72.4±10.8 | [redacted] | 47.8% |
| Hartl 2016[111] | European countries | 16,016 | 70.8±10.8 | [redacted] | 32.2% |
| Hasegawa 2016[112] | USA | 3084 | [redacted] | 70 (61–79) | 50.0% |
| Hegewald 2020[114] | USA | 2445 | 68.4±11.6 | [redacted] | 50.7% |
| Hemenway 2017[115] | USA | 369 | 66 | [redacted] | 57.5% |
| Huertas 2017[116] | Spain | 150 | [redacted] | 70 (65–76) | 3.0% |
| Ingadottir 2018[117] | Iceland | 121 | 73.7±9.0 | [redacted] | 57.0% |
| Islam 2015[120] | USA | 350 | Not reported | [redacted] | 54.9% |
| Iyer 2016[121] | USA | 422 | 64.8±11.7 | [redacted] | 49.9% |
| Jacobs 2018[122] | USA | 1,055,830 | [redacted] | 68 (59–77) | 58.5% |
| Janson 2020[123] | Sweden | 51,247 | 74.6±10.1 | [redacted] | 54.8% |
| Jing 2016[127] | China | 8 | Not reported | [redacted] | Not reported |
| Jo 2020[128] | South Korea | 15,101 | 73.4±9.7 | [redacted] | 25.4% |
| Johannesdottir 2013[129] | Denmark | 3176 | [redacted] | 72.1 (65.2–77.7) | 55.2% |
| Jones 2020[130] | UK | 1029 | 74.4±9.9 | [redacted] | 49.0% |
| Kasirye 2013[132] | USA | 209 | Not reported | [redacted] | Not reported |
| Kerkhof 2020[135] | UK | 16,661 | 75.1±9.9 | [redacted] | 50.3% |
| Keshishian 2019[136] | USA | 7892 | 78.1±7.6 | [redacted] | 57.7% |
| Kim 2010[139] | South Korea | 77 | 69.2±9.4 | [redacted] | 16.9% |
| Kim 2021[140] | South Korea | 4867 | [redacted] | 75–79 | 30.9% |
| Kishor 2020[143] | India | 100 | 64.0±8.5 | [redacted] | 16.0% |
| Ko 2020[144] | Hong Kong | 346 | 74.9±7.8 | [redacted] | 3.8% |
| Lau 2017[151] | USA | 597,502 | Not reported | [redacted] | 55.3% |
| Law 2016[152] | Australia | 90 | 70.7±9.3 | [redacted] | 50.0% |
| Li 2020[156] | China | 108 | 70.6±9.3 | [redacted] | 21.3% |
| Lindenauer 2014[158] | USA | 25,628 | [redacted] | 69 (61–77) | 56.6% |
| Lindenauer 2018[157] | USA | 2340 | 76.3±7.5 | [redacted] | 56.1% |
| Liu 2007[159] | Taiwan | 100 | 73.8±10.6 | [redacted] | 15.0% |

(*Continued*)

**Table 1** (Continued).

| Study | Country | n | Age (years) | | % Female |
|---|---|---|---|---|---|
| | | | Mean ± SD | Median (IQR) | |
| Loh 2017[160] | USA | 123 | 64.9±11.3 | | 47.2% |
| Marcos 2017[161] | USA | 143 | 72.3±10.0 | | 7.0% |
| Martinez-Gestoso 2021[162] | Spain | 615 | 73.9±10.6 | | 13.8% |
| Myers 2021[168] | USA | 7825 | Not reported | | 55.1% |
| Myers 2021[167] | USA | 333,429 | | 70 (61–80) | 57.1% |
| Nantsupawat 2012[170] | USA | 81 | 73.9 | | 53.1% |
| Narewski 2015[171] | USA | 160 | 63.9±10.8 | | 58.8% |
| Nastars 2019[172] | USA | 298,706 | 77.7±7.7 | | 59.6% |
| Ng 2007[173] | China | 376 | 72.2±8.4 | | 14.9% |
| Nguyen 2015[176] | USA | 2910 | 72±11 | | 57.1% |
| Niu 2021[177] | China | 378 | 75.2±8.9 | | 15.9% |
| Njoku 2022[178] | Australia | 2448 | | 72 (64–80) | 50.1% |
| Osman 1997[180] | UK | 266 | 68.0±9.1 | | 47.0% |
| Ozyilmaz 2013[182] | Turkey | 107 | 66.3±8.6 | | 15.0% |
| Park 2016[185] | South Korea | 339,379 | 71.5±11.6 | | 29.8% |
| Peng 2021[187] | China | 123 | 71.1±9.6 | | 26.8% |
| Pienaar 2015[189] | South Africa | 178 | 63±12 | | 42.1% |
| Ponce Gonzalez 2017[191] | Spain | 361 | 75.0±11.5 | | 21.1% |
| Portoles-Callejon 2020[192] | Spain | 108 | 71.5±11.7 | | 18.5% |
| Pouw 2000[194] | Netherlands | 28 | 70.0±7.2 | | 42.9% |
| Pozo-Rodriguez 2015[195] | Spain | 5174 | Not reported | | Not reported |
| Price 2006[196] | UK | 7529 | Not reported | | Not reported |
| Quintana 2022[198] | Spain | 876 | 73.7±9.4 | | 20.5% |
| Rahimi-Rad 2015[199] | Iran | 100 | 70.8±10.3 | | 31.0% |
| Rinne 2015[203] | USA | 25,301 | 68.9±10.5 | | 3.2% |
| Rinne 2017[202] | USA | 33,558 | 68.7±10.4 | | 3.4% |
| Rinne 2017[201] | USA | 33,558 | 68.7±10.4 | | 3.4% |
| Roberts 2002[204] | UK | 1373 | | 72 (66–78) | Not reported |
| Roberts 2011[205] | UK | 9716 | | 65–74 | 50.0% |
| Roberts 2015[208] | USA | 306 | 70.3±12.3 | | 56.2% |
| Roberts 2016[206] | USA | 3612 | 66.6±12.1 | | 67.2% |
| Roberts 2020[207] | USA | 10,405 | 72.6±10.3 | | 62.3% |

(*Continued*)

**Table 1** (Continued).

| Study | Country | n | Age (years) | | % Female |
|---|---|---|---|---|---|
| | | | Mean ± SD | Median (IQR) | |
| Rodrigo-Troyano 2018[209] | Spain | 106 | 71±8 | | 17.9% |
| Ruby 2020[210] | Egypt | 190 | 63.1±10.1 | | 0.0% |
| Shah 2015[214] | USA | 947,084 | Not reported | | Not reported |
| Shani 2022[215] | Israel | 1203 | 70.6±11.0 | | 37.3% |
| Sharif 2014[216] | USA | 8263 | 56.5±5.7 | | 58.8% |
| Shay 2020[218] | USA | 111 | 67.1±11.7 | | 62.2% |
| Simmering 2016[221] | USA | 286,313 | Not reported | | Not reported |
| Singer 2020[223] | USA | 28,240 | 72.7±8.7 | | 51.9% |
| Singh 2016[224] | USA | 135,498 | | 75–84 | 60.2% |
| Snider 2015[225] | USA | 378,419 | 76.2±6.9 | | 56.8% |
| Stefan 2017[228] | USA | 13,893 | | 69 | 57.6% |
| Stuart 2010[232] | USA | 6322 | 74.7±0.4 | | 48.9% |
| Tran 2016[234] | USA | 375 | 59.3±7.4 | | 64.0% |
| Turner 2014[235] | England | 1942 | Not reported | | Not reported |
| Ushida 2022[236] | Japan | 3396 | 75.0±11.2 | | 20.4% |
| Wang 2013[242] | Norway | 481 | 72.8±10.5 | | 53.4% |
| Wong 2008[244] | Canada | 109 | 63.0±14.5 | | 38.5% |
| Wu 2020[245] | Taiwan | 625 | 76.3±10.6 | | 12.0% |
| Wu 2021[247] | Taiwan | 625 | 76.3±10.6 | | 12.0% |
| Wu 2021[246] | USA | 91 | 60±11 | | 63.7% |
| Yilmaz 2021[249] | Turkey | 110 | 67.8±9.3 | | 18.2% |
| Yu 2015[250] | USA | 18,282 | 56.6±5.8 | | 62.4% |
| Zapatero 2013[253] | Spain | 313,233 | 72.7±15.7 | | 30.3% |
| Zhou 2021[254] | China | 417 | 75±12 | | 20.4% |
| Zhu 2021[255] | China | 239 | | 72 | 16.7% |

**Note**: Blacked out cells indicate that data are not available/applicable.

(Figure 3d). Among laboratory values, lower $FEV_1$ and anemia were the most common predictors (Figure 3e). Use of systemic corticosteroids during hospital admission was the most frequently reported predictor of readmission, among medications used during admission (Figure 3f). Discharge to long-term care or a skilled nursing facility was the most commonly reported predictor of readmission, of assessed predictors after admission (Figure 3f–h). Degrees of significance, and the specific studies reporting on each significant predictor, are reported in Table 3.

For COPD-related readmission, 23 significant predictors were found. The most common patient characteristics that were predictors were older age and prior hospitalization (Figure 4a). Mental health comorbidity, diabetes, high Charlson/Elixhauser comorbidity index, and cancer were the most frequently reported comorbidity predictors of readmission

**Table 2** Studies Assessing Interventions

| Study | Country | n | Age (years) | | % Female |
|---|---|---|---|---|---|
| | | | Mean ± SD | Median (IQR) | |
| Cohort Studies | | | | | |
| Adamson 2016[16] | Canada | 462 | 70.6±13.2 | | 40.9% |
| Agarwal 2018[17] | USA | 1248 | Not reported | | Not reported |
| Alshehri 2021[26] | Saudi Arabia | 80 | 67.0±10.3 | | 41.3% |
| Ankjaergaard 2017[27] | Denmark | 201 | 71.5±10.8 | | 56.7% |
| Ban 2012[32] | Malaysia | 193 | 68.5±8.8 | | 13.0% |
| Bashir 2016[35] | USA | 461 | 71.7±13.3 | | 32.5% |
| Bhatt 2017[39] | USA | 187 | 70.4±11.2 | | 61.0% |
| Collinsworth 2018[61] | USA | 308 | 70.5±12.2 | | 58.4% |
| Cope 2015[64] | UK | 464 | Not reported | | Not reported |
| Dalal 2012[71] | USA | 1936 | 63.9±9.9 | | 55.4% |
| De Batlle 2012[72] | Spain | 274 | 68±8 | | 6.9% |
| Gay 2020[92] | USA | 157 | 70.6±11.2 | | 56.1% |
| Gentene 2021[93] | USA | Not reported | Not reported | | Not reported |
| George 2016[94] | Singapore | 340 | 72.6±9.1 | | 11.8% |
| Gerber 2018[95] | Australia | 381 | 71±12 | | 39.9% |
| Gerrits 2003[96] | Netherlands | 1219 | | 65–74 | 40.4% |
| Gulati 2018[106] | USA | 250 | 69±11 | | 42.0% |
| Ingadottir 2018[118] | Iceland | 99 | | 73.0 (71.0–77.0) | 54.5% |
| Ingadottir 2018[117] | Iceland | 121 | 73.7±9.0 | | 57.0% |
| Jeffs 2005[124] | Australia | 216 | 67.5 | | 63.9% |
| Joyner 2022[131] | USA | 253 | 73.6±7.1 | | 65.2% |
| Kawasumi 2013[133] | Canada | 3723 | 72.8 | | 50.8% |
| Kim 2020[138] | USA | 65 | 62.5±9.0 | | 58.5% |
| Kiri 2005[141] | UK | 2557 | 71.1±9.0 | | 49.6% |
| Kiser 2019[142] | USA | 28,700 | | 60–69 | 53.9% |
| Ko 2014[147]<br>Ko 2021[148] | Hong Kong | 185 | 76.9±7.37 | | 10.3% |
| Lalmolda 2017[149] | Spain | 48 | 72.5±7.2 | | 6.2% |
| LaRoche 2016[150] | USA | 3024 | Not reported | | Not reported |
| Lee 2016[153] | USA | 995 | 67.3±10.5 | | 52.6% |
| Matsui 2017[163] | Japan | 12,572 | 78.4±9.5 | | 18.7% |
| McGurran 2019[164] | USA | 2885 | 70.5±11.5 | | 46.9% |

(*Continued*)

**Table 2** (Continued).

| Study | Country | n | Age (years) | | % Female |
|---|---|---|---|---|---|
| | | | Mean ± SD | Median (IQR) | |
| Moullec 2012[166] | Canada | 189 | 72.1±10.4 | [redacted] | 50.3% |
| Myers 2020[169] | USA | 805,764 | Not reported | [redacted] | 56.3% |
| Nguyen 2014[175] | USA | 4596 | 72.3±10.8 | [redacted] | Not reported |
| Nguyen 2021[174] | USA | 128 | 64.6±9.2 | [redacted] | 56.3% |
| Ohar 2018[179] | USA | 1274 | Not reported | [redacted] | 56.3% |
| Pant 2020[183] | Nepal | 86 | 70.6±11.0 | [redacted] | 47.7% |
| Parikh 2016[184] | USA | 44 | 66 | [redacted] | 40.9% |
| Pendharkar 2018[186] | Canada | 1435 | 70±12 | [redacted] | 48.5% |
| Petite 2020[188] | USA | 358 | 67.1±11.6 | [redacted] | 60.9% |
| Pitta 2006[190] | Belgium | 17 | [redacted] | 69 (60–78) | 5.9% |
| Puebla Neira 2021[197] | USA | 4,587,542 | Not reported | [redacted] | 42.2% |
| Revitt 2013[200] | UK | 160 | 70.4±8.6 | [redacted] | 45.6% |
| Rueda-Camino 2017[211] | Spain | 87 | 70.4±9.3 | [redacted] | 11.5% |
| Russo 2017[212] | USA | 160 | 65.9±10.0 | [redacted] | 52.5% |
| Seys 2018[213] | European countries | 257 | 69.8±10.3 | [redacted] | 33.9% |
| Sharma 2010[217] | USA | 62,746 | [redacted] | 75–84 | 58.6% |
| Shi 2018[219] | China | 6333 | 67.5±9.5 | [redacted] | Not reported |
| Shin 2019[220] | South Korea | 308 | 72.3±9.5 | [redacted] | 23.7% |
| Sin 2001[222] | Canada | 22,620 | 75.1±6.7 | [redacted] | 43.5% |
| Sonstein 2014[226] | USA | 420 | 66.5±11.2 | [redacted] | 49.5% |
| Stefan 2013[227] | USA | 53,900 | [redacted] | 70 (61–78) | 58.0% |
| Stefan 2021[229] | USA | 197,376 | 76.9±7.6 | [redacted] | 58.6% |
| Suh 2015[233] | England | 120 | 70±9 | [redacted] | 51.7% |
| van Eeden 2017[238] | Netherlands | 10 | 62.9±9.6 | [redacted] | 80.0% |
| Werre 2015[243] | USA | 244 | Not reported | [redacted] | Not reported |
| Zafar 2019[252] | USA | Not reported | Not reported | [redacted] | Not reported |
| Zafar 2020[251] | USA | 133 | 60.0±9.8 | [redacted] | 36.1% |
| Randomized Controlled Trials | | | | | |
| Atwood 2022[28] | Canada | 3710 | 71.7±12.4 | [redacted] | 49.7% |
| Benzo 2016[37] | USA | 215 | 68.0±9.5 | [redacted] | 54.9% |
| Bucknall 2012[47] | UK | 464 | 69.1±9.3 | [redacted] | 63.4% |
| Conti 2002[63] | Italy | 49 | 71.8±7.8 | [redacted] | Not reported |

(*Continued*)

**Table 2** (Continued).

| Study | Country | n | Age (years) | | % Female |
|---|---|---|---|---|---|
| | | | Mean ± SD | Median (IQR) | |
| Criner 2018[67] | USA | 64 | 61.7±7.9 | | 60.9% |
| De Jong 2007[73] | Netherlands | 210 | 70.7±8.4 | | 25.3% |
| Deutz 2021[75] | USA | 214 | 74.8±7.3 | | 52.8% |
| Eaton 2006[77] | New Zealand | 78 | 77.3±7.1 | | 53.8% |
| Eaton 2009[78] | New Zealand | 97 | 69.9±9.8 | | 56.7% |
| Garcia-Aymerich 2007[88] | Spain | 113 | 73±8 | | 14.2% |
| Gunen 2007[107] | Turkey | 159 | 64.1±8.9 | | 12.0% |
| Hegelund 2020[113] | Denmark | 100 | | 73 (45–89) | 58.0% |
| Ip 2004[119] | Hong Kong | 130 | 80.5±6.6 | | 0.0% |
| Jennings 2015[125] | USA | 172 | 64.7±10.6 | | 55.2% |
| Jimenez 2021[126] | Spain | 737 | 70.4±9.9 | | 26.5% |
| Kebede 2022[134] | Norway | 40 | 73.8±8.2 | | 62.5% |
| Khosravi 2020[137] | Iran | 60 | 71.0±8.9 | | 28.3% |
| Ko 2011[146] | Hong Kong | 60 | 73.6±7.0 | | 1.7% |
| Ko 2017[145] | Hong Kong | 180 | 74.8±8.2 | | 4.4% |
| Ko 2021[148] | Hong Kong | 136 | 75.0±7.6 | | 2.9% |
| Lellouche 2016[154] | Canada | 50 | 72±8 | | 46.0% |
| Li 2020[155] | China | 378 | 66.3±8.1 | | 15.9% |
| Monreal 2016[165] | Spain | 120 | | 71 (61–78) | 33.3% |
| Ozturk 2020[181] | Turkey | 61 | 62.5±8.6 | | 11.5% |
| Pourrashid 2018[193] | Iran | 62 | 63.4±8.5 | | 16.1% |
| Stolz 2007[230] | Switzerland | 226 | 69.5 | | 50.4% |
| Struik 2014[231] | Netherlands | 201 | 63.7±8.3 | | 58.7% |
| Utens 2012[237] | Netherlands | 139 | 68.0±10.8 | | 38.1% |
| Vanhaecht 2016[239] | European countries | 342 | 69.9±10.3 | | 32.2% |
| Vermeersch 2019[240] | Belgium | 301 | 65.5±9.5 | | 43.9% |
| Wang 2016[241] | China | 191 | 72.9±9.6 | | 28.3% |
| Xia 2022[248] | China | 337 | | 70.0 (65.0–75.0) | 16.9% |

**Note**: Blacked out cells indicate that data are not available/applicable.

(Figure 4b). Longer hospital length of stay, higher eosinophil count, and home oxygen after discharge were also frequently reported predictors of readmission (Figure 4c and e). Degrees of significance, and the specific studies reporting on each significant predictor, are reported in Table 4.

Six prediction scores – the BODEX index,[23] CODEX index,[23] CORE score,[247] DOSE index,[23] PEARL score,[143] and RACE scale[151] – were reported to be predictive of all-cause readmission. The included components of each prediction score are reported in Table 5. CORE, PEARL, and RACE were reported to have good predictive value for readmission as a time-to-event outcome variable. The BODEX index, CODEX index, and DOSE index were reported to have good predictive ability for 2–3-month readmission. The CODEX index was reported to have good predictive ability for 6–12-month readmission (Table 3).

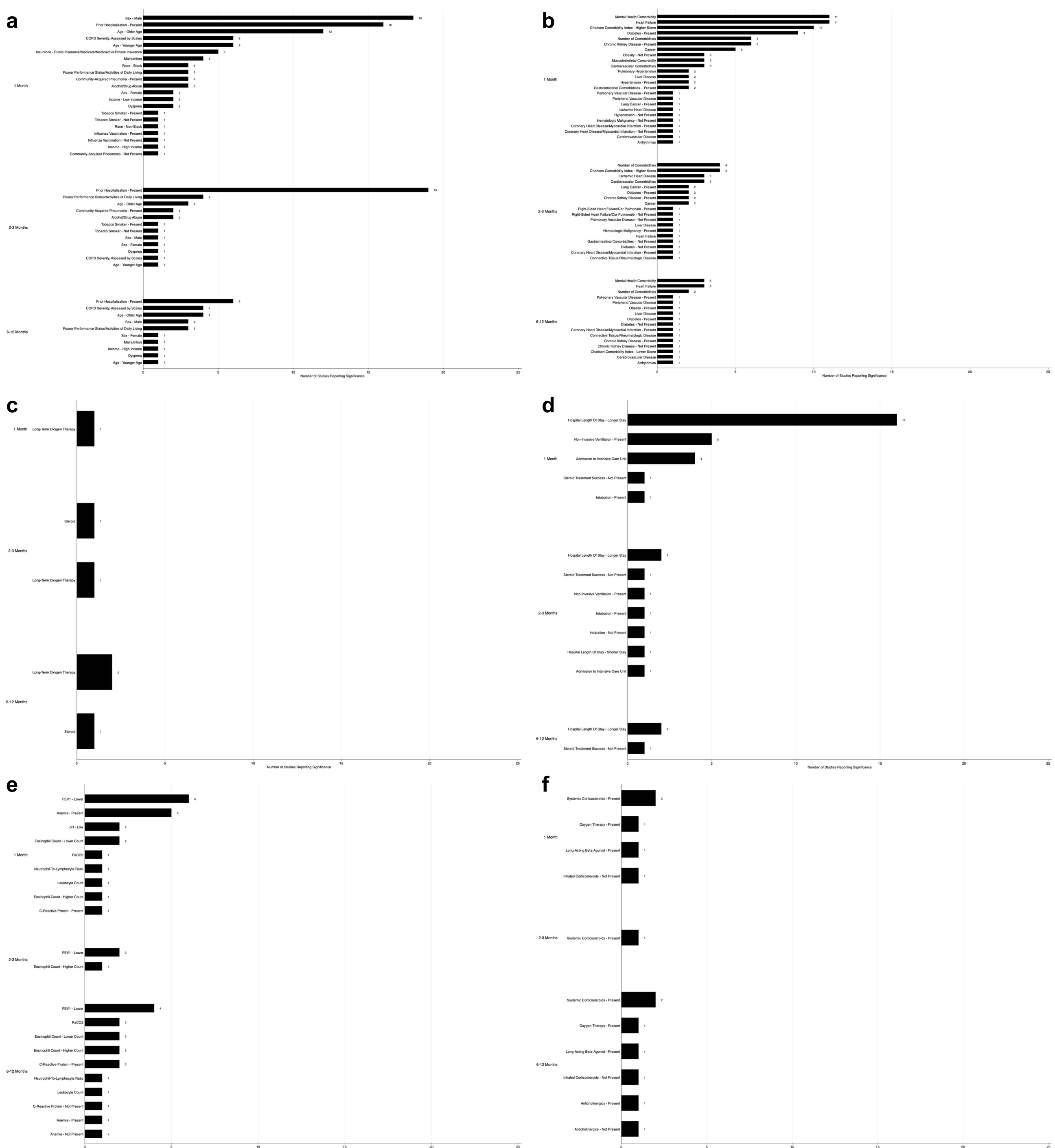


**Figure 3** Continued.

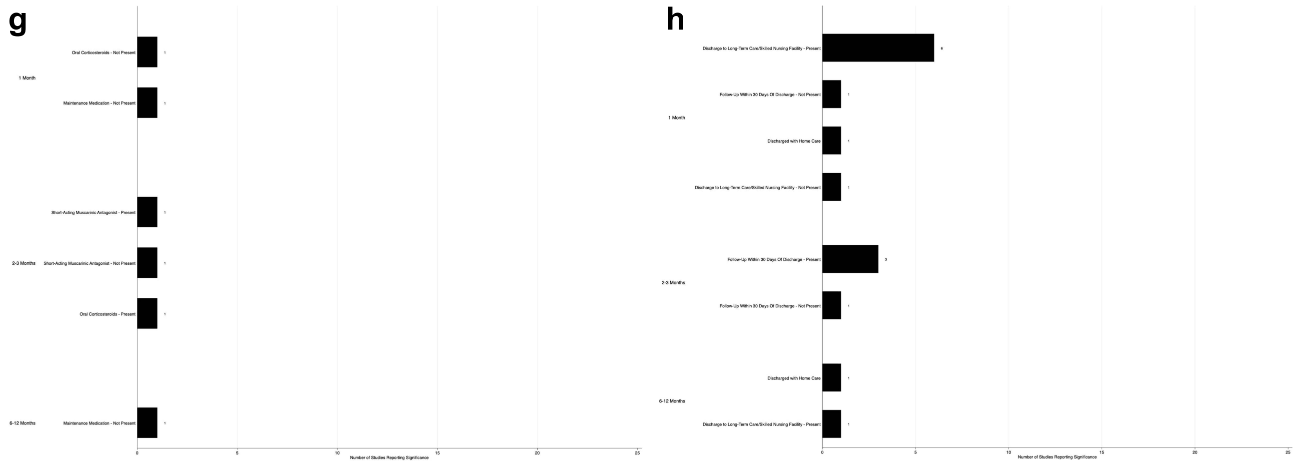


**Figure 3** Significant predictors of all-cause readmission: (**a**) patient characteristics; (**b**) comorbidities; (**c**) medications prior to admission; (**d**) hospital care; (**e**) investigations; (**f**) medications during hospitalization; (**g**) medications on discharge; (**h**) disposition.

Some studies reported significant interventions that can reduce all-cause and COPD-related readmission, most notably use of a COPD-specific care package (Supplementary Tables 3 and 4). Most studies reporting on interventions reported that their intervention was not associated with a significant reduction in readmission rates.

## Discussion

This is the largest systematic review to date, reporting on predictors for readmission of patients with COPD, with 242 articles reporting on 16,471,096 patients included in this review. We comprehensively report on predictors for both all-cause and COPD-related readmissions, for readmission at 1 month, 2–3 months, and 6–12 months. The included studies originated from around the world, and there was generally a low risk of bias. There were 64 predictors for all-cause readmission and 23 predictors for COPD-specific readmission. Significant predictors for all-cause readmissions included 1) pre-admission patient characteristics, such as male sex, prior hospitalization, poor performance status, number and type of comorbidities, and use of long-term oxygen; 2) hospitalization details, such as length of stay, use of corticosteroids, and use of ventilatory support; 3) results of investigations, including anemia, lower $FEV_1$, and higher eosinophil count; and 4) discharge characteristics, including the use of home oxygen and discharge to long-term care or a skilled nursing facility.

Several prior systematic reviews have also reported on predictors. Alqahtani et al reviewed 14 studies, stating that comorbidities, previous exacerbations/hospitalizations, and increased length of initial hospital stay were major risk factors for 30- and 90-day all-cause readmission.[8] Heart failure, renal failure, depression, and alcohol use were also associated with increased 30-day all-cause readmission, with being female described as a protective factor for readmission. Bahadori and Fitzgerald examined 17 studies, and found that previous hospital admission, dyspnea, and oral corticosteroids were significant risk factors for readmission.[9] Njoku et al reviewed 57 studies, and found that hospitalization in the year prior to index admission, comorbidities (such as asthma), living in a deprived area, and living in/or discharge to a nursing home were key predictors of COPD-related readmission.[10]

This review identifies some notable predictors worth highlighting that are not contained in previous studies, which were parsimonious. While prior studies reported heart failure and neuromuscular disease, we identified other significant preadmission comorbidities, including alcohol use, diabetes, and mental health. Similarly, poor performance status and malnutrition were both identified as important predictors of readmission. In-hospital use of critical care, including non-invasive ventilation, invasive ventilation, and ICU stay, was also identified as predictors. Use of steroids was also predictive of readmission; this was probably related to the severity of disease. Eosinophil count was both correlated and inversely correlated in different studies. While all studies excluded corticosteroid use prior to measurement of the

**Table 3** Significant Predictors for All-Cause Readmission

| Variable Type | Type I Error | 1 Month | 2–3 Months | 6–12 Months |
|---|---|---|---|---|
| Patient Characteristics | | | | |
| Age | <0.05 | Correlated[29,53,105,172]<br>Inversely correlated[191] | Correlated[38]<br>Inversely correlated[183] | Correlated[53,66,127] |
| | <0.01 | Correlated[33,49,50,123,185,233,253]<br>Inversely correlated[34,122,151,214,221] | Correlated[111,123] | Correlated[123]<br>Inversely correlated[76] |
| | Not reported | Correlated[29] | | |
| Alcohol/drug abuse | <0.05 | Correlated[29] | | |
| | <0.01 | Correlated[49,224] | Correlated[34,205] | |
| | Not reported | | | |
| Community-acquired pneumonia | <0.05 | Correlated[83,210]<br>Inversely correlated[208] | Correlated[254] | |
| | <0.01 | Correlated[50] | Correlated[50] | |
| | Not reported | | | |
| COPD severity, assessed by scales | <0.05 | | | |
| | <0.01 | Correlated[25,49,50,105,247,250] | Correlated[50] | Correlated[53,55,127,244] |
| | Not reported | | | |
| Dyspnea | <0.05 | Correlated[54] | Correlated[38] | Correlated[84] |
| | <0.01 | Correlated[105] | | |
| | Not reported | | | |
| Income | <0.05 | Correlated[215] | | |
| | <0.01 | Inversely correlated[122,224] | | Correlated[97] |
| | Not reported | | | |
| Insurance: public insurance/Medicare/Medicaid vs private insurance | <0.05 | | | |
| | <0.01 | Correlated[49,53,122,128,151] | | |
| | Not reported | | | |

(*Continued*)

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**Table 3** (Continued).

| Variable Type | Type I Error | 1 Month | 2–3 Months | 6–12 Months |
|---|---|---|---|---|
| Male | <0.05 | Correlated[16,35,151,172,178,215,216] Inversely correlated[123] | Inversely correlated[123] | Correlated[59] Inversely correlated[123] |
| | <0.01 | Correlated[49,53,74,122,128,140,185,214,224,232] Inversely correlated[253] | Correlated[195] | Correlated[41,76] |
| | Not reported | Correlated[201] | | |
| Malnutrition | <0.05 | Correlated[74] | | Correlated[139] |
| | <0.01 | Correlated[33,74,253] | | |
| | Not reported | | | |
| Poorer performance status/activities of daily living | <0.05 | Correlated[25,84,247] | Correlated[25,195,198] | Correlated[30,84,104] |
| | <0.01 | | Correlated[62] | |
| | Not reported | | | |
| Prior hospitalization | <0.05 | Correlated[54,84,178,212,233] | Correlated[20,38,178,183] | Correlated[178] |
| | <0.01 | Correlated[25,31,49,105,125,172,175,176,208,215,216] | Correlated[22,25,31,45,84,89,91,111,125,195,198,209,212,215] | Correlated[41,55,81,87,104] |
| | Not reported | | Correlated[62] | |
| Race: black | <0.05 | Inversely correlated[172] | | |
| | <0.01 | Correlated[102,151,214] | | |
| | Not reported | | | |
| Tobacco smoker | <0.05 | Correlated[247] | Correlated[45] | |
| | <0.01 | Inversely correlated[253] | Inversely correlated[38] | |
| | Not reported | | | |
| Vaccination: influenza | <0.05 | Correlated[170] | | |
| | <0.01 | Inversely correlated[232] | | |
| | Not reported | | | |

| | | | | |
|---|---|---|---|---|
| Comorbidities | | | | |
| Number of comorbidities | <0.05 | Correlated[29,34,35,123,172] | Correlated[38,123] | Correlated[123] |
| | <0.01 | Correlated[122] | Correlated[34,205] | Correlated[244] |
| | Not reported | | | |
| Arrhythmias | <0.05 | Correlated[24] | | Correlated[56] |
| | <0.01 | | | |
| | Not reported | | | |
| Cancer | <0.05 | | Correlated[31] | |
| | <0.01 | Correlated[31,33,49,50,253] | Correlated[50] | |
| | Not reported | | | |
| Cardiovascular comorbidities | <0.05 | Correlated[34,103] | Correlated[38,198] | |
| | <0.01 | Correlated[49] | Correlated[34] | |
| | Not reported | | | |
| Cerebrovascular disease | <0.05 | | | |
| | <0.01 | Correlated[49] | | Correlated[31] |
| | Not reported | | | |
| Charlson comorbidity index | <0.05 | Correlated[74,215,255] | Correlated[195,215] | Inversely correlated[178] |
| | <0.01 | Correlated[33,50,128,175,176,214,253] | Correlated[50,111] | |
| | Not reported | | | |
| Chronic kidney disease | <0.05 | Correlated[54] | Correlated[31] | Inversely correlated[76] |
| | <0.01 | Correlated[33,49,50,122,250] | Correlated[50] | Correlated[31] |
| | Not reported | | | |
| Connective tissue/rheumatologic disease | <0.05 | | | Correlated[31] |
| | <0.01 | | Correlated[208] | |
| | Not reported | | | |

(*Continued*)

**Table 3** (Continued).

| Variable Type | Type I Error | 1 Month | 2–3 Months | 6–12 Months |
|---|---|---|---|---|
| Coronary heart disease/myocardial infarction | <0.05 | | Correlated[31] | |
| | <0.01 | Correlated[49]<br>Inversely correlated[255] | | Correlated[31] |
| | Not reported | | | |
| Diabetes | <0.05 | Correlated[212,232] | Correlated[31,205]<br>Inversely correlated[111] | Correlated[108] |
| | <0.01 | Correlated[31,33,49,122,151,176,232] | | Correlated[30] |
| | Not reported | | | |
| Gastrointestinal comorbidities | <0.05 | Correlated[212] | Inversely correlated[208] | |
| | <0.01 | Correlated[49] | | |
| | Not reported | | | |
| Heart failure | <0.05 | Correlated[24,29,216,232] | | Correlated[56,108] |
| | <0.01 | Correlated[31,33,49,122,176,250,253] | Correlated[31] | Correlated[31] |
| | Not reported | | | |
| Right-sided heart failure/cor pulmonale | <0.05 | | Inversely correlated[208] | |
| | <0.01 | | Correlated[205] | |
| | Not reported | | | |
| Hematologic malignancy | <0.05 | | | |
| | <0.01 | Inversely correlated[208] | Correlated[208] | |
| | Not reported | | | |
| Hypertension | <0.05 | Correlated[212,232] | | |
| | <0.01 | Inversely correlated[49] | | |
| | Not reported | | | |


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| | | | | |
|---|---|---|---|---|
| Ischemic heart disease | <0.05 | Correlated[232] | Correlated[20] | |
| | <0.01 | | Correlated[50,205] | |
| | Not reported | | | |
| Liver disease | <0.05 | | | Correlated[31] |
| | <0.01 | Correlated[31,49] | Correlated[31] | |
| | Not reported | | | |
| Lung cancer | <0.05 | | | |
| | <0.01 | Correlated[50,216] | Correlated[50,205] | |
| | Not reported | | | |
| Mental health comorbidity | <0.05 | Correlated[25,29,176] | | Correlated[66,97,108] |
| | <0.01 | Correlated[14,49,83,151,216,224,232,250] | | |
| | Not reported | | | |
| Musculoskeletal comorbidity | <0.05 | | | |
| | <0.01 | Correlated[216,232,247] | | |
| | Not reported | | | |
| Obesity | <0.05 | | | Correlated[84] |
| | <0.01 | Inversely correlated[74,122,253] | | |
| | Not reported | | | |
| Peripheral vascular disease | <0.05 | | | |
| | <0.01 | Correlated[49] | | Correlated[31] |
| | Not reported | | | |
| Pulmonary hypertension | <0.05 | | | |
| | <0.01 | Correlated[176,250] | | |
| | Not reported | | | |

(*Continued*)




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**Table 3** (Continued).

| Variable Type | Type I Error | 1 Month | 2–3 Months | 6–12 Months |
|---|---|---|---|---|
| Pulmonary vascular disease | <0.05 | | Inversely correlated[208] | |
| | <0.01 | Correlated[250] | | Correlated[56] |
| | Not reported | | | |
| Medications Prior to Admission | | | | |
| Long-term oxygen therapy | <0.05 | Correlated[24] | Correlated[183] | Correlated[100] |
| | <0.01 | | | Correlated[104] |
| | Not reported | | | |
| Steroid | <0.05 | | Correlated[215] | Correlated[244] |
| | <0.01 | | | |
| | Not reported | | | |
| Hospital Care | | | | |
| Admission to ICU | <0.05 | Correlated[172,224,250] | Correlated[183] | |
| | <0.01 | Correlated[214] | | |
| | Not reported | | | |
| Hospital length of stay | <0.05 | Correlated[25,33,172,216,224,250] | Correlated[38]<br>Inversely correlated[183] | Correlated[76,104] |
| | <0.01 | Correlated[49,50,105,122,128,140,185,202,214,253] | Correlated[50] | |
| | Not reported | | | |
| Intubation | <0.05 | | Inversely correlated[208] | |
| | <0.01 | Correlated[49] | Correlated[111] | |
| | Not reported | | | |
| Non-invasive ventilation | <0.05 | Correlated[74,212] | | |
| | <0.01 | Correlated[33,49,247] | Correlated[38] | |
| | Not reported | | | |

| | | | | |
|---|---|---|---|---|
| Steroid treatment success | <0.05 | Inversely correlated[69] | | Inversely correlated[69] |
| | <0.01 | | Inversely correlated[69] | |
| | Not reported | | | |
| | | Investigations | | |
| Anemia | <0.05 | | | Correlated[108]<br>Inversely correlated[76] |
| | <0.01 | Correlated[33,49,175,176,250] | | |
| | Not reported | | | |
| C-reactive protein | <0.05 | Correlated[60] | | |
| | <0.01 | | | Correlated[53,127]<br>Inversely correlated[76] |
| | Not reported | | | |
| Eosinophil count | <0.05 | Inversely correlated[135,199] | Correlated[114] | Correlated[65]<br>Inversely correlated[76,156] |
| | <0.01 | Correlated[247] | | Correlated[114] |
| | Not reported | | | |
| $FEV_1$ | <0.05 | Inversely correlated[204,235,249] | Inversely correlated[89,182] | Inversely correlated[66] |
| | <0.01 | Inversely correlated[105,212,247] | | Inversely correlated[53,87,104] |
| | Not reported | | | |
| Leukocyte count | <0.05 | | | |
| | <0.01 | Correlated[60] | | Correlated[76] |
| | Not reported | | | |
| Neutrophil-to-lymphocyte ratio | <0.05 | | | |
| | <0.01 | Correlated[60] | | Correlated[76] |
| | Not reported | | | |

(*Continued*)

**Table 3** (Continued).

| Variable Type | Type I Error | 1 Month | 2–3 Months | 6–12 Months |
|---|---|---|---|---|
| $PaCO_2$ | <0.05 | | | Correlated[100,139] |
| | <0.01 | Correlated[105] | | |
| | Not reported | | | |
| pH | <0.05 | Inversely correlated[105,255] | | |
| | <0.01 | | | |
| | Not reported | | | |
| Medications During Hospitalization | | | | |
| Anticholinergics | <0.05 | | | Correlated[87] |
| | <0.01 | | | Inversely correlated[104] |
| | Not reported | | | |
| Inhaled corticosteroids | <0.05 | | | |
| | <0.01 | Inversely correlated[208] | | Inversely correlated[55] |
| | Not reported | | | |
| Oxygen therapy | <0.05 | | | |
| | <0.01 | Correlated[175] | | Correlated[31] |
| | Not reported | | | |
| Long-acting beta-agonist | <0.05 | Correlated[176] | | |
| | <0.01 | | | Correlated[55] |
| | Not reported | | | |
| Systemic corticosteroids | <0.05 | Correlated[175] | | |
| | <0.01 | Correlated[176] | Correlated[31] | Correlated[31,76] |
| | Not reported | | | |
| Medications on Discharge | | | | |
| Oral corticosteroids | <0.05 | Inversely correlated[216] | Correlated[195] | |
| | <0.01 | | | |
| | Not reported | | | |

| | | | | |
|---|---|---|---|---|
| Maintenance medication | <0.05 | Inversely correlated[232] | | |
| | <0.01 | | | Inversely correlated[234] |
| | Not reported | | | |
| Short-acting muscarinic antagonist | <0.05 | | | |
| | <0.01 | | Correlated[208]<br>Inversely correlated[208] | |
| | Not reported | | | |
| | | Disposition | | |
| Discharged with home care | <0.05 | | | Correlated[81] |
| | <0.01 | Correlated[214] | | |
| | Not reported | | | |
| Discharged to long-term care/skilled nursing facility | <0.05 | Correlated[74,232]<br>Inversely correlated[224] | | Correlated[108] |
| | <0.01 | Correlated[35,49,122,128] | | |
| | Not reported | | | |
| Follow-up within 30 days of discharge | <0.05 | | Correlated[125]<br>Inversely correlated[91] | |
| | <0.01 | Inversely correlated[216] | Correlated[182,198] | |
| | Not reported | | | |
| | | Prediction Scores | | |
| BODEX index[23] | | | $p$=0.008 | |
| CODEX index[23] | | | $p$<0.0001 | $p$<0.0001 |
| CORE score[247] | $p$<0.001 | | | |
| DOSE index[23] | | | $p$<0.01 | |
| PEARL score[143] | $p$<0.0001 | | | |
| RACE scale[151] | $R^2$=0.923 | | | |

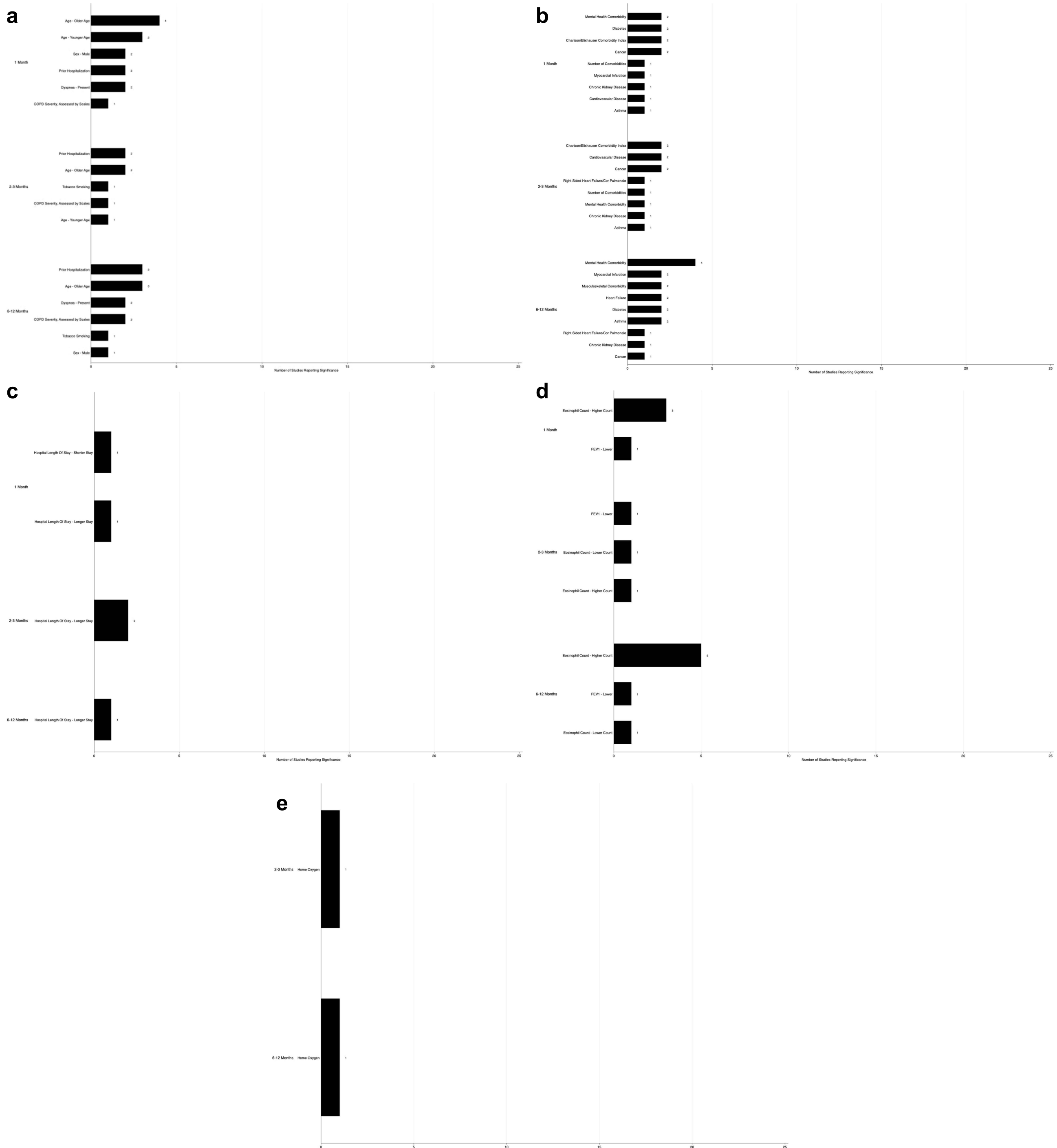

**Figure 4** Significant predictors of COPD-related readmission: (**a**) patient characteristics; (**b**) comorbidities; (**c**) hospital care; (**d**) investigations; (**e**) medications on discharge.

eosinophil count, the studies used various cut-offs to define eosinopenia.[114,135,199,247] Further research to determine the utility of eosinophil count is needed.

With COPD patients having a high all-cause readmission rate of 50%[5] and being the largest single group of chronic disease patients reported in the literature, identifying those at greatest risk of readmission is a priority as more resources can be directed to this group. This comprehensive systematic review identifies many predictors across multiple domains, including prior to admission, during hospitalization, and post-hospitalization. Current prediction rules for readmissions

**Table 4** Significant Predictors of COPD-Related Readmission

| | Type I Error | 1 Month | 2–3 Months | 6–12 Months |
|---|---|---|---|---|
| Patient Characteristics | | | | |
| Age | <0.05 | Correlated[219,245] | | Correlated[31,129,234] |
| | <0.01 | Correlated[50,110]<br>Inversely correlated[34,48,206] | Correlated[50,110]<br>Inversely correlated[34] | |
| | Not reported | | | |
| COPD severity, assessed by scales | <0.05 | | | Correlated[21,187] |
| | <0.01 | Correlated[50] | Correlated[50] | |
| | Not reported | | | |
| Dyspnea | <0.05 | Correlated[116] | | Correlated[21] |
| | <0.01 | Correlated[206] | | Correlated[206] |
| | Not reported | | | |
| Male | <0.05 | | | Correlated[129] |
| | <0.01 | Correlated[48] | | |
| | Not reported | Correlated[201] | | |
| Prior hospitalization | <0.05 | | | Correlated[129] |
| | <0.01 | Correlated[31,70] | Correlated[22,31] | Correlated[21,31] |
| | Not reported | | | |
| Tobacco smoking | <0.05 | | | |
| | <0.01 | | Correlated[34] | Correlated[206] |
| | Not reported | | | |
| Comorbidities | | | | |
| Number of comorbidities | <0.05 | | | |
| | <0.01 | Correlated[219] | Correlated[34] | |
| | Not reported | | | |
| Asthma | <0.05 | | | Correlated[129] |
| | <0.01 | Correlated[206] | Correlated[50] | Correlated[206] |
| | Not reported | | | |
| Cancer | <0.05 | Correlated[31,50] | Correlated[31,50] | |
| | <0.01 | | | Correlated[31] |
| | Not reported | | | |
| Cardiovascular disease | <0.05 | Correlated[34] | Correlated[34] | |
| | <0.01 | | Correlated[135] | |
| | Not reported | | | |

(*Continued*)

**Table 4** (Continued).

| | Type I Error | 1 Month | 2–3 Months | 6–12 Months |
|---|---|---|---|---|
| Charlson/Elixhauser comorbidity index | <0.05 | | Correlated[22] | |
| | <0.01 | Correlated[48,50] | Correlated[50] | |
| | Not reported | | | |
| Chronic kidney disease | <0.05 | | | |
| | <0.01 | Correlated[50] | Correlated[50] | Correlated[31] |
| | Not reported | | | |
| Diabetes | <0.05 | Correlated[206] | | |
| | <0.01 | Correlated[70] | | Correlated[31,206] |
| | Not reported | | | |
| Heart failure | <0.05 | | | |
| | <0.01 | | | Correlated[31,206] |
| | Not reported | | | |
| Right-sided heart failure/cor pulmonale | <0.05 | | | Correlated[21] |
| | <0.01 | | Correlated[22] | |
| | Not reported | | | |
| Mental health comorbidity | <0.05 | | | Correlated[21,129] |
| | <0.01 | Correlated[121,206] | Correlated[121] | Correlated[121,206] |
| | Not reported | | | |
| Musculoskeletal comorbidity | <0.05 | | | Correlated[129] |
| | <0.01 | | | Correlated[206] |
| | Not reported | | | |
| Myocardial infarction | <0.05 | | | |
| | <0.01 | | | Correlated[31,129] |
| | Not reported | Correlated[99] | | |
| Hospital Care | | | | |
| Hospital length of stay | <0.05 | Inversely correlated[110] | | Correlated[187] |
| | <0.01 | Correlated[50] | Correlated[50,110] | |
| | Not reported | | | |
| Investigations | | | | |
| Eosinophil count | <0.05 | Correlated[114] | | Correlated[112]<br>Inversely correlated[156] |
| | <0.01 | Correlated[114,245] | Correlated[114]<br>Inversely correlated[135] | Correlated[36,65,114,187] |
| | Not reported | | | |

(*Continued*)

**Table 4** (Continued).

| | Type I Error | 1 Month | 2–3 Months | 6–12 Months |
|---|---|---|---|---|
| $FEV_1$ | <0.05 | | | |
| | <0.01 | Inversely correlated[34] | Inversely correlated[34,135] | Inversely correlated[245] |
| | Not reported | | | |
| Medications During Admission | | | | |
| Oxygen therapy | <0.05 | | | |
| | <0.01 | Inversely correlated[185] | | Correlated[31] |
| | Not reported | | | |
| Medications on Discharge | | | | |
| Home oxygen | <0.05 | | | Correlated[21] |
| | <0.01 | | Correlated[22] | |
| | Not reported | | | |

**Table 5** Characteristics of Prediction Scores

| | CODEX | BODEX | PEARL | CORE | RACE |
|---|---|---|---|---|---|
| **Patient characteristics** | Comorbidity<br>Number of severe exacerbations (ED or admission) mMRC scale | BMI<br>Number of severe exacerbations (ED or admission) mMRC scale | Age<br>Previous admissions<br>Left heart failure/ right heart failure<br>eMRC scale<br>Right heart failure | Lung function<br>Neuromuscular disease<br>exacerbations<br>Triple inhaler management | Age<br>Gender<br>Income<br>Race<br>Payer<br>Comorbidities |
| **Hospitalization management** | – | – | – | – | |
| **In-hospital investigations** | $FEV_1$% | $FEV_1$% | | Eosinophil count | |
| **Discharge characteristics** | – | – | – | – | |

have areas under the receiver operating characteristics curve in the range 0.70–0.72, and may be limited by lacking variables in all domains (Table 5). The findings from this systematic review can be used to develop other prediction scores with higher predictive power. The findings can also be used in clinical practice to help identify individual patients who may benefit from more resources to reduce their risk of readmission. While most prediction scores for COPD readmission are parsimonious, having five or fewer variables for ease of use, a more complicated model with more predictors may be more accurate. More complex models may be enabled through the increase in electronic patient records, which enable more discrete data elements as well as computer decision support.[256]

This review was not without limitations. There was heterogeneous reporting on some predictor variables; many studies used different cut-off points for predictor variables. We therefore reported on the general directionality of a predictor variable as it relates to readmission. We have reported the predictors as reported by the studies, using their original cut-off points and without any synthesis, in Supplementary Tables 1 and 2. In addition, we were unable to report non-significant predictors owing to non-uniform reporting and therefore the total number of studies investigating each predictor. It is therefore unclear how many studies investigated specific predictors, and what proportion of them reported significant correlation with readmission. For certain predictors that may not be as well studied (eg malnutrition), there could be underestimation of importance.

It is also important to note that some published literature suggests that not all patients discharged with a diagnosis of "COPD" have spirometrically confirmed COPD, and therefore patients discharged with "COPD" may in fact have other comorbidities, such as congestive heart failure.[257] Therefore, caution is needed in the interpretation of some of the included studies, given that they simply included patients with a diagnosis of COPD which may not necessarily be confirmed on spirometry. Future studies could look to assess only patients who have spirometrically confirmed COPD.

There may also be some concerns over the generalizability of individual studies to the larger population of patients with COPD admitted to hospitals. There were three studies[127,190,238] with sample sizes of less than 20, and another three studies[80,134,194] with sample sizes of 20–40 patients. Moreover, there were three studies[98,119,210] with no females included in the sample, and another 52 studies[20–23,29,32,38,42,51,53,68–70,72,74,88,90,91,94,116,139,143–149,155,159,161–163,173,177,181,182,190,192,193,201–203,209,211,245,247,249,255] where less than 20% of the sample comprised of females. Reassuringly, the significant predictors reported by these studies agree with larger and more representative studies. In addition, a large proportion of the studies originated from the USA, which may make the results of this review more generalizable to the US population and slightly less generalizable to other countries, especially given the lack of a universal healthcare system in the USA and therefore the potential confounding effect on readmissions.

In conclusion, we found that predictors of readmissions after an admission for COPD exacerbation included patient characteristics prior to and at admission, hospitalization management, results from admission investigations, and discharge characteristics. Findings from this review may enable better model generation if predictors from all these domains are included. These findings may also be used to identify new predictors in the different domains and can be used by clinicians to help generate their gestalt of readmission.

## Disclosure

The authors report no conflicts of interest in this work.

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